ABSTRACT

Reaction injection molding is a technique which involves simultaneous polymerization and processing of reactive monomers or pre-polymers in an open (free rise foams) or closed mold cavity (integral-skin foams) to produce foamed plastics In this process a low boiling material (blowing agent, typically fluorocarbon), and or a chemical agent (e g , water) which reacts and generate gas, is added to the monomers, to obtain polymeric foams They find numerous uses in a variety of industries Among them polyurethane is the most important commercially

For the free rise foams, the existing models of the foaming process only predict the bulk density of the foamed plastic or foam rise dynamics as a function of the initial blowing agent concentration, and for integral-skin foams apart from the aforementioned characteristics, skin thickness is predicted They ignore the nucleation and growth of bubbles and hence are inadequate for predicting the bubble size distribution in either kind of foam Bubble size distribution is an aspect which is worth investigating since many properties of interest, such as mechanical, thermophysical, thermal conductivity etc , of foamed plastics are strongly dependent on its micro structure The present work therefore attempts to model the formation and growth of bubbles in the reaction mixture, thus making it possible to obtain the bubble size distribution in addition to foam density, foam rise dynamics for both free rise foams and integral-skin foams To control the skin thickness for integral-skin foams, various process variables are tested

In this work we consider polyurethane foams obtained by reaction injection molding under conditions of free rise, blown by freon alone, water alone and a mixture of both The population balance equation for bubbles, which is coupled with the system of energy balance and reaction kinetics equations through the blowing agent evaporation rate expression, is solved by the method of characteristics, for the freon alone and water alone case, and by a numerical technique for a mixture of freon and water, to obtain the bubble size distribution. The rate expression for bubble nucleation is selected from the existing theories applicable to polymeric solutions A simple mass transfer coefficient approach

for expressing growth rate of bubbles is used in such a way that it can accommodate various growth laws, without affecting the solution procedure

It is found that the main factors that determine bubble size and its distribution in free rise foaming process are foaming period (the time period between inception of nucleation and gel point) For physical blowing agent (freon) it is seen that with the increase in initial blowing agent concentration, the foaming period increases and bigger bubbles are obtained since more time is available for growth For a chemical blowing agent (water) the trend is found to be exactly opposite, i e , the bubble size distribution becomes narrower with the increase in the blowing agent concentration This is because of the increased rate of the exothermic reaction and consequent increase in nucleation rate

When both physical (freon) and chemical (water) blowing agents are present it is found that the nucleation period decreases with increase in water concentration and for a given water concentration same thing occurs with increase in freon concentration Addition of a little amount of water thus offers a technique to control the bubble size distribution Here, the effect of addition of external nuclei is also studied It is found that nucleation can be effectively suppressed by addition of external nuclei and hence bubble size distribution can be very effectively controlled by such technique

A one-dimensional model for predicting foaming dynamics, density profile and bubble size variation in freon blown integral-skin foams is developed As solving the population balance equation itself along the height of the mold is computationally very intensive, moments of the population balance equation are solved instead to make predictions It is found that the existing equilibrium models predict integral-skin foam to form for even very low blowing agent concentrations, whereas the present model predicts premature gelation for such low concentrations Three parameters initial concentration of the blowing agent, initial fraction of the volume of the mold filled and the mold wall temperature are varied to see the effect on final density profile and the profile of mean bubble size inside the mold With increase in blowing agent concentration, thickness of both the bottom and top skin increases, while the overall density of the foamed core decreases.

In foamed core mean bubble size increases for more initial blowing agent concentration. With the increase of the initial fraction of the mold filled, the bottom skin increases drastically, while the thickness of the upper skin obtained increases only marginally Mean bubble size profile shows a maximum near the bottom skin, which decreases with the increase in fraction of the mold volume filled initially Finally, with the increase in mold wall temperature the thickness of the bottom skin decreases and the top skin increases marginally, with a higher overall core foam density Mean bubble size shows a maximum near the bottom skin as in the previous case, but with the increase of the mold wall temperature, the peak decreases It is predicted that controlling the top skin thickness is difficult and the most effective parameter for controlling the thickness of the bottom skin is the initial fraction of the mold filled